DeMOTTE

Effect of Gases
and Vapours upon
Plant Activities

Science
B. A.

1902

The Effect of Gases and Vapours upon Plant Activities

BY

RUBY THORNE DeMOTTE

THESIS

FOR THE

DEGREE OF BACHELOR OF ARTS

IN THE

COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

1902

UNIVERSITY OF ILLINOIS

May 31, 1902

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Ruby Thorne DeMotte

ENTITLED "The Effect of Gases and Vapours upon Plant Activities"

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Arts in the College of Science

Chas. F. Hottes.

Approved, T. J. Burrill

HEAD OF DEPARTMENT OF Botany

The Effect of Gases and Vapours upon Plant Activities.

Introduction.

The vital activities of a plant, growth, photosynthesis, respiration, transpiration, etc., are greatly affected by conditions of the external world. Each of the many activities of a plant organism plays between definite boundaries, and the conditions necessary for it to function at its optimum are, in most cases, very different from those most favorable for any other function. When, because of some abnormal or unusual external condition, any particular function is accelerated, retarded, or inhibited, the other functions must undergo some change such that equilibrium and harmonious cooperation may be restored. If the plant is unable, by the combined activities of its functions, to compensate for the unnatural effect of the environment upon this one function, its vitality is seriously affected. When moisture is reduced to a minimum, the plant, to economize with the water at

its disposal, closes the stomates in response to a stimulus which the guard cells receive due to this insufficient supply of water. This closure of the stomates, however, seriously interferes with the photosynthetic activity of the plant because the gases must now diffuse through the cuticula. Growth is greatly retarded, not simply because the water at the disposal of the plant is insufficient, but likewise because the amount of the food products of photosynthesis is less than the needed supply. Thus various functions of the plant are so mutually interdependent, so intimately correlated, that any change in the external relationships affecting the activity of one, must also influence the others. Since the various activities of the plant require very different conditions for their optimal function, we can never find a combination of external conditions at which all the life processes are at their best. On the other hand, these external conditions may be so adjusted that the various plant activities are neither greatly accelerated nor greatly retarded but work in full harmony. This harmonious action of the various functions is known as the ecological optimum.

One of the fundamental characteristics of plant life, indeed of all living matter, is

irritability the quality of reacting in response to stimuli. Many activities of the plant are directly due to, or greatly affected by external stimuli. Growth is a vital process, taking place in response to stimuli. Every stimulus must reach a certain minimum intensity before it has an effect, and even then it may not produce the same results at all times. Also, different stimuli, under different conditions or the same conditions, may produce the same response. The inherent disposition of a plant may determine, to a certain extent, the effect of any given stimulus upon it. The response may be greatly modified, however, by external agencies; for example, the response to a particular phototactic stimulus may be quite opposite at different temperatures. Strasburger noticed that swarm-spores of Haematococcus and Ulothrix, exposed to a constant intensity of light, are positively phototactic at a temperature of 16°C. to 18°C., but when subjected to a temperature of 40°C., are negatively phototactic. The response of a plant may depend not only on one stimulus but on several. The nyctitropic movements of the geonyctitropic plants take place only in the absence of light and only when gravitation is allowed to act upon the plants. On the clinostat where gravitation is neutralized and the stimulus

of geotropism is lacking, no nyctitropic movements take place even in the dark. Geotropism, in such an instance, may be looked upon as a sensitizer.

Materials and Methods.

The reagents used were oxygen, carbon dioxide, hydrogen, illuminating gas, formaldehyde, carbon bisulphide, ammonium hydroxide, camphor and ether.

The experiments were tried upon the seeds and seedlings of Phaseolus, Pisum, Zea mais, and Vicia faba and twigs of Syringa, well leaved out.

The nutrient solution used was made up by the following formula:

Potassium chloride	.25 gr.
Magnesium sulphate	.25 "
Potassium phosphate	.25 "
Calcium nitrate	1.00 "
Water (distilled)	1000. cc.

Water or nutrient solution was rendered free of gases by boiling vigorously for about fifteen minutes. It was then sealed while hot in 250 cc. flasks with paraffine, or in Mason quart jars.

For sealing the seedlings in vessels of boiled water, a paraffine was used which melted at about 35°C. so that the plants

would not be injured.

Germination chambers. (a) For one kind of germination chamber, a 300 cc. bell-jar, graduated in 100 cc. spaces, was used. A small, cylindrical, wire-netting basket for the seeds was supported in the jar upon the end of a glass tube, which passed through a cork fitted very tightly into the mouth of the jar. The lower end of the tube rested in a small bottle of potassium hydroxide for absorbing the carbon dioxide given off by the seeds in germination. The bell-jar, in position, stood inverted, containing about 100 cc. of water, above which the basket of seeds projected into any atmosphere desired, supplied by displacement of water.

(b.) Another vessel which served as a germinator, was a large, glass jar of about two and a half liters capacity. 200 cc. of water was placed in it. A small, wire-netting basket for the seeds hung in the jar, suspended by cords which were held in place in the large, hollow, glass stopper by plaster of Paris. The ground edge of the stopper was smeared with vaseline, so that when the stopper was placed in the jar, the seeds hung in a moist, air-tight chamber.

(c.) A third form of germinating chamber was a quart (about 950 cc.) milk-bottle, with a pasteboard lid. The seeds were suspended

in a mosquito-netting bag by a cord which was put through the pasteboard lid and held by a knot. About 70 cc. of water was placed in the jar. Then to render it air tight it was sealed with paraffine.

Except where otherwise stated, the experiments were carried on at a temperature of 17°C. to 25°C.

All measurements of length are given in centimeters and all weights in grams.

Oxygen.

General. Absorption of oxygen is necessary for the maintenance of plant life, for it is by the oxidation of certain substances in the plant that energy is liberated for carrying on the vital functions. Although there probably exists an optimum oxygen-pressure for every organism,— within considerably wide extremes, respiration is not dependent upon the oxygen-content of the medium. In fact, Pfeffer says that the respiratory activity of many plants is not greatly modified when the percent of oxygen is reduced to one half its normal amount or when its partial-pressure is increased from five to ten times. Stich, of Leipzig, who performed a number of experiments upon plants under decreased oxygen-pressure, says that some plants in air containing only 2% of oxygen, not quite one tenth the amount normally present in the atmosphere, give off the normal amount of carbon dioxide. However, excessive oxygen-pressure or the absence of oxygen are very harmful, in fact, fatal to the life of aerobes. Sandsten found that in an atmosphere of free oxygen, the movements of the protoplasm in the staminal hair of

Tradescantia are greatly accelerated for from five to seven minutes, then are gradually retarded and finally cease. After a time the cell dies. He found also, that while seeds germinate readily in free oxygen, the seedlings do not grow as rapidly as in ordinary air. Growing shoots kept in an atmosphere containing from 25% to 100% of free oxygen, remain unaltered for 20 days, but upon removal to the ordinary atmosphere, slowly die. On the other hand, if the oxygen-pressure is below a certain minimum, the requirements of the plant are not supplied. Growth ceases, and because of the close correlation of the plant functions, all the life processes are seriously interfered with. However, it requires some little time to exhaust the supply of free oxygen in the plant, so that growth may continue for a time in the absence of oxygen. Wieler observed, in the case of seedlings of Helianthus annuus, distinct growth in an atmosphere containing not more than .0003% by volume of it. In such a case, oxygen-respiration is reduced to a minimum and perhaps completely checked, and intramolecular respiration only is active.

Any change in external conditions destroying the equilibrium of the plant activities acts as a stimulus; hence any

departure from the normal oxygen-pressure must also be considered a stimulus, producing independent results, or modifying the nature of the response to other stimuli acting simultaneously with it. Pfeffer says that a decreased atmospheric pressure acts as a stimulus upon aerobes, causing temporary acceleration of growth, which reaches its maximum value when the air is from one fourth to one seventh rarefied. This is due, not only to the decreased atmospheric pressure, but also to the lowering of the partial-pressure of oxygen, as is shown by experiments in which the oxygen is replaced by some indifferent gas so that the normal atmospheric pressure is retained.

Oxygen and Growth.

Under this topic are considered the effects of different amounts of oxygen upon the germination of seeds and the growth of seedlings.

Experiment 1. Seeds of Phaseolus and Zea mais were used. Of each kind, six groups of six seeds each were selected, and the dry weight of each group was determined. Then the seeds were put into six flasks of boiled water, groups No. 1 of both corn and beans into flask No. 1, and so on. The flasks numbered

1, 3, and 5 contained tap-water, and those numbered 2, 4, and 6 contained distilled water. Flasks 1 and 2 were set with a tolerably vigorous current of air bubbling through the water. Flasks 3 and 4 were again sealed as soon as the seeds were dropped into them. The contents of flasks 5 and 6 were poured into two shallow dishes numbered respectively 5 and 6. Twenty-four hours later each group of seeds was taken from the water and weighed, and the percentage of water absorbed in each case was estimated.

Table I.

			Zea mais.			Phaseolus.		
No.	Soaked in	Oxygen content	Dry weight.	Weight 24 hours later.	% water absorbed.	Dry weight.	Weight 24 hours later	% water absorbed
1.	Tap-water.	Maximum.	2.58	3.35	29.8	2.95	6.43	117.9
2.	Distilled water.	Maximum	2.75	3.56	29.4	2.45	5.5	124.5
3.	Tap-water.	Minimum.	2.6	3.36	29.2	2.9	6.27	116.2
4.	Distilled water.	Minimum	2.53	3.3	30.4	2.7	6.1	125.9
5.	Tap-water.	Normal.	2.6	3.3	26.9	3.05	6.6	116.4
6.	Distilled water.	Normal.	2.6	3.4	30.8	2.95	6.33	114.6

The above table shows that the percentage of water absorbed in twenty-four hours is much greater in the case of Phaseolus, but there is no definite relation between the amount of oxygen present in the water, and the percentage of water absorbed; hence the imbibition of water by soaking seeds is not a vital process but a purely physical one. Nor did the kind

of water whether distilled or not, have any effect upon the amount absorbed by the seeds.

After the twenty-four hours' soaking, the seeds were taken from the water and placed in exactly the same conditions for germination. Germination chamber (a) was used, one group of seeds, including both corn and beans, being placed in each chamber in an atmosphere half air and half hydrogen. Within twenty-four hours after the seeds had been placed in these jars, all the corn had sprouted. The beans never grew. The corn in groups 1 and 2 was quite evidently a little farther along than in the other groups, and there was a slight difference between groups 3 and 4, and 5 and 6, the latter ones being a little ahead. At the end of another twenty-four hours, the difference between the several groups was more marked; the corn was about the same in groups 1 and 2, but had longer radicles than all the others, and that in groups 3 and 4 was the slowest of all. So the seeds soaked in water containing a maximum amount of oxygen, are hastened in germination, and those soaked in water deprived of its oxygen, are retarded. It seems to make no difference whether the water is distilled or not.

Experiment 2. Three flasks of boiled tap-water were numbered 7, 9 and 11 and three of boiled distilled water were numbered 8, 10, and 12. Into each flask were dropped six grains of corn. Then, as in Exp. 1, flasks 7 and 8 were placed with a current of air passing through them; flasks 9 and 10 were sealed, and the contents of flasks 11 and 12 were poured into shallow dishes so that a considerable surface of water was exposed to the air.

Forty hours later, the seeds in flasks 7 and 8, which had a maximum of oxygen, had germinated, the radicles being just through the seed-coats. The embryos in groups 11 and 12 were more swollen than in groups 9 and 10, but in no seeds in these groups had the radicles broken through.

The seeds were observed again in two hours. A slight growth was noticeable in the seeds of groups 7 and 8 but no difference could be seen in groups 11 and 12. In the sealed flasks 9 and 10, the embryos of all the seeds were swollen more, and in No. 10 one radicle had just broken the seed-coats.

Twenty hours later, sixty-two hours after the seeds were put into the water, all the seeds of groups 11 and 12 had sprouted. The seeds in 7 and 8 were growing, most of the radicles slanting upward. In flask 10

four grains had the tips of the radicles just through the seed-coats but none are sprouted in flask 9.

During the next three days, the seeds in 11 and 12 grew a little, but after this they apparently made no progress, and soon died, with some sort of mould growing upon them. Usually in a germinating corn grain the radicle keeps ahead of the plumule and grows to a considerable length before a secondary root is started. In these seeds, completely immersed, the radicle grew till it was about 5 mm. long, then it seemed unable to grow any more. The plumule grew to about the same length, then stopped, and by this time a small protuberance appeared on the embryo between the radicle and plumule, the beginning of the first secondary root. At this point growth ceased. The plants had evidently starved, and it must have been for lack of oxygen, because the grains contained plenty of reserve food material. The seeds in the sealed flasks quit growing about twenty four hours sooner than did those in the shallow dishes; but they had grown more slowly and were not nearly so far along. Only one had split the seed-coats the full length of the embryo so that the plumule could be seen; in four others only the tips of the radicles had

appeared. The seeds had been able to carry on the activities of germination only so long as there was available oxygen in the tissues surrounding the embryo; when this supply was exhausted, growth had to cease.

The seeds in flasks 7 and 8 grew slowly for eight days after those of groups 11 and 12 had apparently quit growing. One seed in flask 7, which lay just at the lower end of the tube admitting the air, where it was continually agitated by the bubbling air, grew much faster than any others. After fifteen days and a half from the time the seeds were placed in the water, they grew no more, and when examined two days later, they were decaying. Several grains had roots two centimeters long and plumules very little shorter, but most of them had not grown so much. The one in flask 7 which kept so much ahead of the others, had a primary root 6 cm. long and two secondary roots each about 5 cm. long, while the plumule was almost 2.5 cm. long. The first leaf was almost ready to burst through the sheath. It was examined for stomates, and they were found to be fewer than on normally grown leaves of the same stage of development and abnormal in shape. When this seedling was taken from the water, its tissues were saturated and the

stem had rotted off.

Table II.

No.	Seeds in	Oxygen content	Time required for germination.	Duration of growth after germ.	Length of radicle.
7	Tap-water.	Maximum	40 hrs.	334 hrs	1 seed, 6 cm. others, 2 cm
8.	Distilled water.	Maximum	40 hrs.	334 hrs.	1 cm.
9.	Tap-water.	Minimum.	*		
10.	Distilled water	Minimum	1 seed, 42 hrs. others, 62 hrs	† 72 hrs.	.2 cm.
11.	Tap-water.	Normal.	62 hrs.	96 hrs.	.5 cm.
12.	Distilled water.	Normal.	62 hrs.	96 hrs.	.4 cm.

*None germinated, partly covered with paraffine.
†Grew much more slowly than those of 11 and 12.

From this table we see that the seeds which had a maximum of oxygen in the water germinated sooner than normally and grew faster and for a longer time than any of the other seeds. The seeds in boiled water germinated just as soon as, and in case of one seed, sooner than, those in the water which contained absorbed oxygen. As respiration, the use of oxygen by the tissues, is essential to growth, the seeds must have carried on intramolecular respiration, deriving their oxygen from their own tissues. This supply was soon exhausted, however, and growth had to cease here sooner than where the water contained some oxygen.

The radicles of most of the seedlings, especially those in flasks 7 and 8, grew obliquely upward toward the surface of the water. This

was due to the stimulus of aërotropism. Roots, when immersed in water where the oxygen supply is insufficient tend to grow towards the surface of the water where the oxygen content is greater. Water will not absorb as much oxygen as the roots need. Molisch observed that if corn-seedlings are fastened over a surface of water, the roots grow through the water with very unnatural curvings and bendings, or turn upward and grow along the surface of the water, where more oxygen is at hand.

The final death of the seedlings, even in the water containing the most oxygen was due to their inability to adapt themselves to the immersed condition. The water could not absorb sufficient oxygen to supply their needs. Also the tissues became saturated, thus interfering with growth, and disintegration soon began.

The seeds in groups 9, 10, 11 and 12 were taken from the water twelve days after they were put in and planted in moist sawdust Those in group 9 had been somewhat covered with paraffine and none had germinated. The others had not grown any for six days and were partly covered with mould. Two days later, fourteen days from the time the seeds were put to soak, five seeds of groups 11 and 12 had roots 3 cm. long and stems only a little shorter. An 8 da. seedling,

grown normally, placed in moist saw dust after twenty-four hours' soaking, had roots 20 cm. long and a stem 8 cm. long. So the seedlings left in water after germination, where the proper supply of oxygen was not available, were very greatly retarded in growth.

Experiment 3. 18 corn grains were put to soak in ordinary tap-water. Twenty-four hours later, 6 grains were planted in moist sawdust. Within another twenty-four hours all the seeds in the saw-dust had germinated; but of the seeds in the water none had even the tips of the radicles through the seed-coats. The next day, the seeds in sawdust were growing well; the radicles were .8-1.2 cm. long but the plumules scarcely showed outside the seed-coats. In the seeds in the water the embryos were more swollen and two or three looked as if the radicle were about to break through. Four days after the experiment was started, the corn in the sawdust had radicles 1.8-3.7 cm. long and plumules .4-1.1 cm. long. Of the twelve seeds in the water, one had the seed coats over the embryo split and another had just the very tip of the radicle through the seed-coats. No others had germinated.

This shows the comparative growth for the first four days of seeds immersed in

water containing the ordinary amount of oxygen, and of those grown normally, having been left in water only twenty-four hours. The seeds left in water are very much retarded, probably because of an insufficient supply of oxygen, the intercellular spaces being filled with water instead of air, and because the soaking in water for so long a time interferes with the action of diastase and the preparation of food for the embryo.

Experiment 4. Four seedlings of Vicia faba were selected as near the same size as possible, 8.5 - 11 cm. tall. Two plants were placed in a wide-mouthed bottle filled with boiled nutrient solution and numbered 1. The short arm of a J-tube was then inserted and the bottle was sealed with paraffine. The long arm of the J-tube rested in a small bottle of boiled nutrient solution sealed with liquid paraffine. This was for the purpose of replacing the liquid absorbed by the plants and thus maintaining equilibrium of pressure. Two seedlings were placed in an open bottle of unboiled nutrient solution, numbered 2. Within three days it was evident that the plants in No. 2 grew the faster as shown in Table III. By the sixth day growth was even more retarded in No. 1 and the plants began

to wilt. The jar No. 1 was unsealed and a current of air was set to passing through the water. Observations were again recorded four days later. During all this time the solution in No. 1 had been vigorously agitated by the passing current of air but the plants had not revived. The root system of one seemed to be decaying and it was thrown out. The bottle with the other plant was set into the greenhouse. The plants in No. 2 had been growing vigorously and stood 19 and 29 cm. tall. Two days after No. 1 was set back into the greenhouse, the plant had completely revived; the leaves were standing in a natural position, turgid and apparently healthy. It had grown very little or not at all for the preceding six days, however, so that it was not nearly so tall as the plants in No. 2.

Table III.

a.- Height of plant from cotyledons to growing point.
b.- Increase in growth in length since last observed.
c.- Average daily growth.

No.	Roots in	1st da.	3rd day.			6th day.			10th day.			12th day.
		a	a	b	c	a	b	c	a	b	c	
1.	Boiled Nut. Sol.	8.5	10	1.5	.75	10	0	*0	†			⊕
		9.5	11	1.5	.75	12	1	.33				
2.	Unboiled Nut. Sol.	8.5	10	1.5	.75	13.5	3.5	1.16	19	5.5	1.4	
		11.	14	3	1.5	17	3	1	29	12	3	

*Plants wilted. Current of air set to bubbling through the solution.

†Plants still wilted. Rootsystem of one decaying, so it was thrown out.

⊕The remaining plant quite revived.

Experiment 5. Six 4 days-old seedlings of Vicia faba were selected, with roots 8-9 cm. long and the plumules still curled down between the cotyledons. Two seedlings were placed in ordinary tap-water in an open vessel numbered 3; then as described in Exp. 4, two were sealed in boiled nutrient solution, numbered 4, and two in boiled distilled water numbered 5. Table IV shows the results of the observations.

Table IV.

a, b, and c, same as in Table III.

No.	Roots in	1st da.	16th day			20th day			30th day		
		a	a	b	c	a	b	c	a	b	c
3.	Unboiled	*1	19	18	1.2	27	8	2	33	6	.6
	tap-water.	1	24	23	1.5	28	4	1	35	7	.7
4.	Boiled	*1	15	14	.9	20	5	1.2	29	9	.9
	Nut. Sol.	1	16	15	1	26	10	2.5	38	12	1.2
5.	Boiled	*1	11	10	.66	13.5	2.5	.62	14	.5	.05
	dist. water.	1	12	11	.7	17	5	1.2	19	2	.2

*Plumules still curled down between cotyledons.

For the first sixteen days the plants in unboiled tap-water grew more rapidly than any of the others, but during the remaining time of the experiment, the plants in the boiled nutrient solution grew the fastest; so it seems that the plants whose roots have no oxygen but can get nutrient salts are not at such a disadvantage as those whose roots have access to oxygen but are not supplied with nutrient salts. This acceleration of growth may be due to the combined effect of the stimuli of decreased oxygen pressure and the presence of

nutrient salts. (Compare the effect of these stimuli upon transpiration, Exp. 1 under Oxygen and Transpiration). The plants in boiled nutrient solution absorbed many times more water than did those in boiled distilled water.

Experiment 6. Six 5 days-old seedlings of Vicia faba were selected quite uniform in size. Each root was marked with India ink one centimeter from the tip. Three seedlings were placed in a vessel of boiled tap-water numbered 6, and the vessel was sealed. The three remaining seedlings were placed in an open vessel of ordinary tap water, numbered 7. Records of the observations are given in the following table:

Table V.

a.- Length of root below mark.
b.- Daily growth in length of roots.
c.- Average daily growth.

No.	Roots in	1st da.	2nd day.			3rd day.			4th day			5th day			7th day		
		a	a	b	c	a	b	c	a	b	c	a	b	c	a	b	†c
6.	Boiled tap-water.	1	2.5	1.5		4.4	1.9		6.	1.6		6.9	.9		9.5	1.3	
		1	2.3	1.3	1.26	3.5	1.2	1.43	5.5	2.	1.4	6.8	1.3	1.06	7.5	.35	.8
		1	2	1		3.2	1.2		3.8	.6		4.5	1.		6.	.75	
7.	Unboiled tap-water.	1	2.5	1.5		3.8	1.3		5.5	1.7		6.7	1.2		8.	.65	.35
		1	2.3	1.3	.96	3.5	1.2	1.23	5.	1.5	1.43	5.7	.7	.9	5.8	.05	
		1	1.1	.1		2.3	1.2		3.4	1.1		4.2	.8		*4.	-.1	

*Root tip had rotted off.
†Daily growth less than before because secondary roots had become quite vigorous.

From the above table it is seen that the average daily growth of the roots was greater in the case of the plants in boiled water every day

except the fourth, and then it was very little less. This acceleration of growth, according to Pfeffer, is in response to the stimulus furnished by the decreased partial-pressure of oxygen. By the fourth day after setting up the experiment it was quite evident that the aërial parts of the plants in unboiled water were growing much faster than the others. At the end of the week the plants in No. 7 were taller and had broader and hardier leaves. The root-systems showed a difference in appearance also. Where the plants had their roots deprived of oxygen, the tap-roots were a little thicker and the secondary roots were not so numerous. The tap-roots of all the plants had short longitudinal splits through the outer tissues, and in the plants of No. 6, very small bubbles of some gas seemed to be given off here. This, according to Pfeffer, was probably air, carried down from the aërial parts of the plant. In this way, the roots obtained their necessary supply of oxygen. Pfeffer says that frequently the roots of plants growing in a stiff clay soil can not obtain for themselves a sufficient supply of oxygen, so it must be carried to them from the atmosphere through the aërial parts of the plant; also that the roots of the seedlings of Vicia faba, Pisum, etc., can when necessary, obtain the required amount of oxygen in this way.

Oxygen and Transpiration.

The object of the experiments performed was to determine the effect upon the transpiration of a plant of depriving its roots of oxygen.

The plants used were goodsized seedlings of Vicia faba.

Burgerstein says in his Arbeiten des pflanzenphysiologischen Institutes der K. K. Wiener Universität, that the transpiration of plants growing in nutrient solution is less than that of plants growing in distilled water, and becomes proportionately less as the solution is more concentrated; also that while a very weak nutrient solution, e.g. .01%, retards transpiration a little, the same concentration of single salts in solution accelerates transpiration.

In Exp. 5, under Oxygen and Growth, it was observed that plants in boiled nutrient solution absorbed many times more water than did those in boiled distilled water. As the plants wilted in neither case, the transpiration of those in nutrient solution must have been proportionately greater. This reversal of the results of Burgerstein must have been due to the stimulating effect of the decreased partial-pressure of oxygen observed by Pfeffer. In unboiled distilled water the transpiration is greater

than in unboiled nutrient solution. When the oxygen-pressure was decreased in both cases, the transpiration in the nutrient solution became very much greater than that in the distilled water. If the plants in each case had responded to this stimulus in the same degree, the amounts of transpiration would have retained the same ratio. However, the result observed shows that the stimulating effect of the decreased oxygen-pressure was so much greater in the case of the nutrient solution that the transpiration was accelerated until it was not only equal to, but much greater than, that of the plants in distilled water. Thus, these two stimuli, which when acting separately retard transpiration, if acting simultaneously, instead of intensifying the individual effect of each, call forth an exactly opposite response.

Experiment 1. Three milk bottles were numbered 1, 2, and 3. No. 1 was filled with ordinary tap-water, No. 2 with boiled tap-water, and No. 3 with boiled nutrient solution. Two plants were placed in each bottle and sealed in with paraffine. Each bottle was weighed and set into the greenhouse. Twenty-four hours later they were weighed again to determine the loss of weight due to transpiration. Each bottle

was emptied and refilled with unboiled tap-water, weighed, and returned to the green-house. Twenty-four hours after this they were again weighed to see whether the loss of the same plants by transpiration varies according to whether the roots have access to oxygen or not. This was repeated several times, the plants all being in unboiled tap-water on alternate days. The results are given in the following table:

Table VI.

a.– Weight at beginning of twenty-four hours.
b.– Weight at end of twenty-four hours.
c.– Loss of weight by transpiration.
d.– Increase in loss while in unboiled water.

	No.	Roots in	First day. a	b	c	Roots in	Second day. a	b	c	d
Trial 1.	1.	Unboiled tap-water.	1715.8	1674.1	41.7	Unboiled tap-water.	1717.7	1679.5	38.2	-3.5
	2.	Boiled tap-water.	1741	1680	61	Ditto.	1743.5	1676	67.5	6.5
	3.	Boiled Nut. Sol.	1761.7	1709.2	52.5	Ditto.	1763	1696.5	66.5	14.

	No.	Roots in	First day. a	b	c	Roots in	Second day. a	b	c	d
Trial 2.	1.	Unboiled tap-water.	1715.5	1673.5	42	Unboiled tap-water	1720.5	1671	49.5	7.5
	2.	Boiled tap-water.	1745	1667.3	77.7	Ditto.	1748	1659	89	11.3
	3.	Boiled Nut. Sol.	1763.5	1695	68.5	Ditto.	1767	1692.7	74.3	5.8

	No.	Roots in	First day. a	b	c	Roots in	Second day. a	b	c	d
Trial 3.	1.	Unboiled tap-water.	1717.5	1677	40.5	Unboiled tap-water	1719.7	1676.7	43	2.5
	2.	Boiled tap-water	1747	1670.5	76.5	Ditto.	1750.7	1668	82.7	6.2
	3.	Boiled Nut. Sol.	1768.5	1697	71.5	Ditto.	1770.5	1694.5	76	4.5

The comparison of the losses on alternate

days means nothing in case of No. 1 for the medium is constantly unboiled tap-water. The differences must be due to the gradual increase of leaf surface as the plant grows and to other external conditions besides the oxygen supply, such as the temperature and the humidity of the atmosphere. For example, the decrease in transpiration the second in the first trial must have been due to the condition of the atmosphere. This serves to make more striking the increased loss of weight on the second day in No.'s 2 and 3. For although conditions were less favorable for transpiration on the second day, plants 2 and 3 transpired considerably more on that day when their roots were in unboiled water than on the previous day with their roots in boiled water. Each day that the plants were transferred to unboiled water, they transpired more than when their roots were deprived of oxygen.

In trials 2 and 3, in the case of the plants in boiled nutrient solution, the increase in transpiration when they were changed to the unboiled water was less than that of the plants changed from boiled to unboiled water. Hence the simultaneous effect of decreased oxygen-pressure and the presence of nutrient salts, is a stimulus accelerating transpiration, as in the case discussed above,

comparing boiled distilled water and nutrient solution in this regard. In trial 2, the increase in transpiration in No.3 on the second day, was less than in No.1 even, so that there was not as much of an increase as might have been due to the growth of the plants and the more favorable external conditions; i.e. the transpiration of the plants the first day while in boiled nutrient solution was comparatively greater than that of the plants in unboiled tap-water all the time. From this Table VI, we see that the transpiration is retarded when the plants are in water containing a minimum amount of oxygen. Burgerstein says that transpiration is retarded by nutrient solutions proportionately to the strength of the solution; so, as tap-water is a very weak nutrient solution, the regular nutrient solution retards transpiration as compared to it. Now these two stimuli which have the same individual effects, call forth quite an opposite response when combined. In trial 1, the plants seem not to have adjusted themselves to the combined stimuli but responded to both separately, thus adding the individual effects, so that the transpiration was retarded more than twice as much in boiled nutrient solution as in boiled tap-water. In trial 3, the transpiration in No.3 the first day was

-not accelerated beyond that in the control, No. 1, but it was much greater in comparison than that in No 2. If the conditions on the second days are considered normal, the figures in column d show the decrease in loss by transpiration, while the roots of the plants are in boiled water; i.e. the retardation due to lack of oxygen.

Experiment 2. Two milk-bottles, numbered 1 and 2, were prepared just as numbers 1 and 2 in Exp. 1 and weighed at intervals of twenty-four hours. Instead of filling No. 2 with unboiled water each alternate day, it was kept filled with boiled water. The observations were as follows:

Table VII.

a, b, and c, same as in Table VI.

No.	Roots in	First day. a	b	c	Second day. a	b	c
1.	Unboiled tap-water	1746.5	1683.5	63	1740.5	1674.5	66
2.	Boiled tap-water	1767.5	1709.5	58	1765.5	1703	62.5

At the end of the second day some of the leaves of the plants in No. 2 had dried up and fallen off, causing more loss in weight than that due to transpiration, so new plants were placed in bottles just as before. Table VIII gives the results of the observations, for which see next page.

Table VIII.
a, b, and c, same as in Table VI.

No.	Roots in	First day a	b	c	Second day. a	b	c	Third day. a	b	c
1.	Unboiled tap-water	1730	1703.5	26.	1726	1697.5	28.5	1727.5	1691.5	36
2.	Boiled tap-water	1720	1695	25.	1716	1689.5	26.5	1721	1690	31

No.	Roots in	Fourth & Fifth das. a	b	c	Sixth day. a	b	c	Seventh day a	b	c
1.	Unboiled tap-water.	1691.5	1625	66.5	1730.5	1702.5	28	1702.5	1671	31.5
2.	Boiled tap-water	1690	1627.5	62.5	1723.5	1695	28.5	1695	1669.5	25.5

The plants used the first time certainly were not very healthy or they would not have been so seriously affected in such a short time. From Table VIII, we see that, with a very slight exception on the sixth day, the plants with roots in boiled water have their transpiration retarded. As was shown also in Exp. 1, transpiration is retarded by depriving the roots of oxygen.

Oxygen and Absorption.

Experiment 1. Object: to determine how absorption of water by the roots is affected by the oxygen-content of the water.

Two flasks, each with a horizontal delivery tube, supplied with a stop-cock, were filled, one with ordinary tap-water and the other with boiled tap-water. The delivery tubes were of the same size and filled quite to the ends.

In each flask was placed a good-sized seedling of Vicia faba and sealed in with paraffine. The stop-cocks were left open. When the plant transpired, drawing up water from the flask, a partial vacuum was formed there, and the ordinary pressure of the atmosphere at the end of the delivery tube, pushed the water down the tube to take the place of the absorbed water. So the amount of water drawn in from the tube was a measure of the amount absorbed by the plant. The plant whose roots were immersed in ordinary aërated tap-water, between 11:35 A.M. and 2:30 P.M. i.e. in 2 hrs. 55 min., emptied the tube for 202 mm.; that is, at the rate of 1.15 mm. per minute. The plant which stood with its roots in water lacking oxygen, between 11:00 A.M. and 2:30 P.M. in 3 hrs. 30 min. emptied the tube for 118 mm. i.e. at the rate of .538 mm. per minute. The experiment was not continued further because the plants transpired so slowly. The results obtained, however, show that a lack of oxygen in the water surrounding the roots of growing plants, has the effect of depressing the transpiration stream, by retarding the absorption at the roots.

The Effect of Various Gases and Vapours upon the Germination of Seeds and the Subsequent Growth of the Seedling.

General. Growth may be regarded in two ways, - as a mechanical process, in which nutritive compounds are taken into the plant and transformed into the tissues, and as an essentially vital process taking place in response to stimuli. Many chemical agents which are not themselves food and do not enter into the tissues of the plant, may stimulate the growth processes. Small doses of poison may cause a temporary increase in the rapidity of growth. Schulz found that various poisons, such as corrosive sublimate, iodine, bromine, and arsenious acid increase the fermentative activity of yeast; so it is not strange to find that poisons may, at a certain concentration, accelerate growth. At a concentration above the optimum, growth is retarded, so the effect of these poisons is very different from that of nutritive substances; it is due to the irritating properties of the poison. Many experiments have tried in order to determine the effects of different anaesthetics and poisons upon the plant functions. Townsend found that plants kept in a con-

stant atmosphere derived from 1 cc. of ether in 200 cc. of water, showed a constant retardation of growth, and that stronger atmospheres caused a more marked retardation. Seedlings exposed for one hour to the vapour from 5 cc. of ether in 200 cc. of water, showed no marked change in growth but after an hour and a half shock there was an acceleration in growth; after a two hour shock there was first a retardation and then a return to the normal rate of growth, but no acceleration. An exposure of longer than two hours caused a permanent retardation or death. He also found that the vapour from 1 cc. of ether in 100 cc. of water hastens germination, but the seedlings are soon exceeded by the control seeds. Exposure for 7-10 days in an atmosphere from 10 cc. of ether in 100 cc. of water prevented germination, but the vital activities were merely suspended, for these seeds afterwards germinated when removed from the ether vapour. A 12 days' exposure to this vapour destroyed the vitality of the seeds.

Johannsen, a Danish scientist, studied the effect of ether upon plants and found that it acts differently at different temperatures, the action being more intense, the higher the temperature. He took potted lilacs about the first of August and by shocking them with a weak ether vapour

caused them to blossom early in September.

Elfving and Lauren frequently observed that respiration is more active after treatment with ether and chloroform, provided such treatment was not carried so far as to permanently injure the plant.

A number of investigators have found that illuminating gas is very harmful to plants. It keeps the plant from obtaining the needed amount of oxygen, and, according to Boehm, also acts as a direct poison.

Landsten found that very small amounts of ether and chloroform accelerate growth, but that carbon bisulphide in the smallest traces is injurious to growing plants.

Dixon, Bernard, Jumelle, Kosaroff, and others found that the transpiration of plants is depressed by ether, chloroform and carbon dioxide. However an atmosphere of oxygen accelerates transpiration.

Formaldehyde Vapour.

Experiment 1. The seeds of field corn and garden peas were germinated in germination chamber (b). Twelve jars were made ready and numbered from 1 to 12. In the basket in each jar were placed 10 corn grains and 10 peas which had been soaked 24 hours. Then to the 200 cc. of water in each jar was added

40% formaldehyde in the following amounts:

No. 1.	0 cc. (control)	No. 7.	4 cc.
No. 2.	1/4 cc.	No. 8.	5 cc.
No. 3.	1/2 cc.	No. 9.	6 cc.
No. 4.	1 cc	No. 10.	7 cc.
No. 5.	2 cc.	No. 11	8 cc.
No. 6.	3 cc.	No. 12.	9 cc.

The stoppers were put in very tightly so that no vapour could escape.

An observation was made 16 hours after the experiment was started. None of the corn had sprouted but the peas were growing. Some of them had just sprouted before being put into the jars, for it does not take peas so long to germinate as it does corn. At the time of this first observation, the peas in No's 1 and 2 had radicles about .5 cm. long. In No's 11 and 12 about half the peas had the radicles just breaking the seed-coats. The germination in the series from 1 to 12 showed a gradual retardation directly proportional to the amount of formaldehyde vapour present.

24 hours later, the seeds in No. 1 were growing well; the pea radicles were from 2 to 2.5 cm. long and the corn was all growing, two grains having radicles .8 and .9 cm. long. The seeds in No's 2 and 3 had grown some, the corn being about all germinated, but they were noticeably behind the control. Although the seeds in No.s 1, 2, 3, and 4 had all grown a little

since the day before, there was shown a still more marked retardation of growth, the more formaldehyde vapour there was in the jar. In No. 5 only two corn grains had the radicles just through the seed-coats and the peas had grown very little. The radicles were shorter than in No. 4 and more curled. In jars Nos. 6-12, there had been very little or no growth since the day before. A very small percent of the corn grains in Nos. 6 and 7 had just barely germinated but the radicles were abnormally small.

Within 48 hours the effect of the poisonous vapour was very evident. The seeds in the control had grown until the radicles of the peas were 3-3.7 cm. long and the corn, 1-1.5 cm. long. In all the jars containing the vapour, growth had been entirely arrested and the tips of the roots were dying. The experiment was taken down.

Experiment 2. This time the peas were soaked only 12 hours, but half as long as the corn, so that they were more nearly parallel with the corn as to the stage of development. For this experiment the series was as follows, i.e. the number of cubic centimeters of 40% formaldehyde to 200 cc. in each jar:

No. 1	0 cc. (control)	No. 7	2 cc.
" 2.	1/8 cc.	" 8.	2½ cc.
" 3.	¼ cc.	" 9.	3 cc.
" 4.	½ cc.	" 10.	3½ cc.
" 5.	1 cc.	" 11.	4 cc.
" 6.	1½ cc.	" 12.	4½ cc.

21 hours and 30 minutes after the seeds were put into the jars the observations were as follows: in Nos. 1 and 2, no corn grains had sprouted but all the peas were growing, the radicles being .2-.3 cm. long; in Nos. 3 and 4 the pea-radicles were .4-.5 cm. long and the corn embryos were swollen more than in Nos. 1 and 2. The seeds in Nos. 5, 6 and 7 appeared to be just about the same as in Nos. 1 and 2. In No. 8 the germination of the seeds had been somewhat retarded for only four peas had the radicles just through the seed-coats and none of the corn had germinated. The seeds in Nos. 9-12 were about alike, showing very little development since exposed to the vapour. No corn had germinated, and in only one or two peas in each jar had the embryos broken the seed-coats.

During the next 24 hours, the radicles of the peas in the control jar had grown to a length of 2-3 cm., and the corn had just sprouted. In No. 2 the corn had just sprouted also, but the peas were considerably behind those in the control, the radicles being 1-2.5 cm. long

and more unequal in lengths. The seeds in Nos. 3 and 4 were about alike. They were a little farther along than those in No. 2, but had been retarded in comparison with the control seedlings. The pea-radicles were 1.5-2.8 cm. long and not so uniform in length as in No. 1. In Nos. 5 and 6, the seeds were very much behind those in Nos. 3 and 4 and the radicles were curled. The seeds in No 7 were retarded still more and those in Nos. 8-12 had grown none since examined before. Most of the seeds had never germinated.

23 hours after this, a third observation was made. The seeds in the control had grown quite rapidly; the roots of the peas were uniformly 3-3.8 cm. long, much longer than in any other jars. In Nos. 2, 3, and 4 there had been a very slight growth, the pea-radicles being 1.3-2.9 cm. long and healthy in appearance. In Nos. 5, 6, and 7 there had been no further growth and the roots were curled and drying up. The seeds in Nos. 8-12 had changed none since observed before.

Within another 24 hours, while the control peas had grown considerably and were 4-5 cm. long; all the radicles of the seeds in the jars containing vapour, had shrunken and were dried and yellow for about one centimeter from the tips. No growth had taken place since the day before, so the experiment was taken

down.

All the seeds which had not germinated during the experiment were planted in moist sawdust. Four days later, these seeds were carefully examined. Although they had been exposed for four days to the formaldehyde vapour which had suspended all development, now every seed was growing except one pea from No. 10. Looking as the plants as they have grown from the sawdust, it looks as if those seeds which had been exposed to the strongest vapours had grown the best, for the stems stand highest of all. When the complete plants are examined, however, the reason is evident. When a corn grain or a pea is growing naturally, the radicle for the first five or six days keeps much in advance of the stem. In the case of these seeds from No. 12, this was not true, for the stems were almost as long as the roots. The corn plants had stems 3 - 4.5 cm. long, primary roots, 4.5 - 5 cm. long and secondary roots, 6 - 7.5 cm. long. This was after having been soaked for 24 hours, exposed for four days in a two and a half liter jar to the vapour from 4.5 cc. of 40% formaldehyde in 200 cc. of water, and planted in moist sawdust for four days. A corn grain, soaked 24 hours, and then left in moist sawdust for 8 days, had a stem 9 cm. long, a primary root, 22.5 cm. long,

and secondary roots, 18-20 cm. long. This shows how much the seedlings were retarded by the poisonous vapour; and while in the normally grown seedling the primary root was longer than the secondary and 2½ times as long as the stem, in these plants from the seeds exposed to the aldehyde vapour, the primary roots were considerably shorter than the secondary, and were only about 1⅓ or 1½ times as long as the stems. The main roots were retarded so much that the plumules and secondary roots grew faster than normally in proportion. The peas from No. 12 showed the same condition to a striking degree. The roots and stems were about the same length, 2 cm. long, and the stems seemed to be the healthier. The roots were much stunted, and curled and twisted, as though they had had a struggle to grow at all.

The seeds from No. 11 were all growing, and though very, very much retarded, the seedlings were a little larger than those from No. 12. The same relative growth of root and shoot appeared here as in the No. 12 seedlings. The corn plants had stems 5-5.5 cm. long, primary roots, 5.5-6 cm. long, and secondary roots 8-9 cm. long. Of the seeds from No. 10, as said above, one pea had not germinated. The seedlings in this group were a little larger than those of No. 11 but showed the

same relative development of root and stem, though to a less extent. The primary roots were much stunted and curled and the secondary roots were vigorous in comparison.

The plants in group No. 9 were more normal than in Nos. 10, 11, and 12. Of seven pea-plants, two had stems about 1.5 cm. long and roots 3.5 cm. long and naturally decurved, but the other five seedlings were abnormal, the roots being curled and short compared with the stem. The corn plants showed a quite normal relative growth of root and shoot, the stems being 3.5-4 cm. long, the primary roots, 9.5-10 cm. long, and the secondary roots, 7-8 cm. long. Still the plants had been very much retarded, for they were only about one half as large as the normally grown control plant of the same age.

In group No. 8, the plants all showed the normal relative development of parts, but they had been much retarded, almost as much as those of No. 9.

Experiment 3. Experiment 2 was repeated using the first half of the series, Nos. 1-6 as given there. The results of this experiment were discarded as unfair and unsatisfactory, because the same jars were used which had been used in the

two previous experiments without having been thoroughly aired, and the formaldehyde vapour had accumulated, so that when the experiment was set up, the jars contained a much stronger vapour than stated in the series. Consequently the effect was as if 2 or 3cc. of formaldehyde had been added to the water in the jars instead of small parts of 1cc.

Experiment 4. New jars were used this time, germination chambers (c). The series used was about the same as in Experiments 2 and 3, the formaldehyde being added in the following quantities to the 70cc. of water in each jar:

No. 1.	0 cc. (control)	No. 4.	1/6 cc.
" 2.	1/24 cc.	" 5.	1/3 cc.
" 3.	1/12 cc.	" 6.	1/2 cc.

The solutions contain about the same per cent of formaldehyde as in series 1-6 of Experiment 2.

The first observation was made at the end of 18 hours; the seeds were just beginning to germinate. The number of seeds germinated in each jar was as follows: in No. 1, 4 peas and 3 corn grains; in No. 2, 2 peas and 2 corn grains; in No. 3, 5 peas and 1 corn grain; in No. 4, 7 peas and 5 corn grains; in No. 5, 3 peas and no corn grains; and in No. 6,

1 pea and 2 corn grains. That is, germination was retarded a very little in No. 2, was about the same as in control in No. 3, hastened considerably in No. 4, just as it was in Experiment 2, and retarded most of all in Nos. 5 and 6.

20 hours later the seeds in the control were growing well; in No. 2, the seeds were slightly retarded in growth and in No. 3, still more so. The seedlings in No. 4 were distinctly farther developed than those in Nos. 2 and 3 and a little ahead of the control seedlings. A retardation appeared in the seedlings of Nos. 5 and 6 proportional to the concentration of the vapour.

After 29 hours, a third observation was made. The plants in the control were growing well, but in the other jars the seedlings showed a marked retardation of growth, directly proportional to the amount of the poisonous vapours present, except that those in No. 4 seemed still to be a very little ahead of those in No 3. Growth had quite ceased in case of the seeds in Nos. 5 and 6.

Within another 18 hours, the radicles in groups numbered 5 and 6 showed the characteristic brownish, dried tips. The control plants were still growing well, but all the other plants had almost quit growing. The experiment was taken down.

Conclusions: Germination of corn and peas is hastened a little by exposure to the vapour from ½ cc. of 40% formaldehyde in 200 cc. of water; is not retarded, but very slightly hastened by ¼ cc. in 200 cc. of water and slightly retarded by ⅛ cc. in 200 cc. of water. The vapours from all solutions stronger than ½ cc. in 200 cc. of water delay germination, very slightly in case of the weaker solutions and increasingly as the concentration of the vapour is increased. The subsequent growth of the seedling was retarded in every case, so that where a slight advantage had been gained by hastened germination, it was lost within 24 hours, and the seedlings soon fell behind the control plants. All the plants exposed to the vapour, even the slightest amounts, were killed within four days. Germination was almost entirely prevented by the vapours from 3 cc. in 200 cc. of water, and stronger solutions, but the embryos of the seeds were not killed, for when the seeds were planted in moist sawdust, practically 100% of them grew. However, the tissues had been seriously injured by the vapour, for the growth was abnormal and very much retarded. In Experiment 1, the peas germinated even in the strongest vapours, but this was because they had developed so far before being exposed to the

vapour, that the radicles broke through the seed-coats before the vapour had time to affect them. This was undoubtedly the reason, also, that no hastening of germination was observed as in the other experiments. All growth had ceased after 16 hours' exposure to the vapour.

Ether Vapour.

Experiment 1. Nine germination chambers, form (b.), were prepared. To the 200cc. of water in each jar was added ether in the following quantities:

No. 1.	0 (control)	No. 6.	1½ cc.
" 2.	¼ cc.	" 7.	2 cc.
" 3.	½ cc.	" 8.	3 cc.
" 4.	¾ cc.	" 9.	4 cc.
" 5.	1 cc.		

15 hours after the seeds were exposed to the ether, some had begun to germinate. In No. 1, 3 corn grains and 1 pea had germinated. Nos. 2 and 3 were about the same as the control; 3 seeds had germinated in each. In No. 4 only 1 corn grain had the radicle just through the seed-coats; in No. 5, 2 peas had just germinated; in Nos. 7-9 there had been no germination.

24 hours later the retarding effect of the ether was quite noticeable. The seeds in the control were growing well. A few more seeds had germinated in the other jars but growth was very slow. The radicles began to curl when about 1 cm. long. Still no seeds in Nos. 8 and 9 had germinated.

In another day, growth had ceased in Nos. 6-9 and in the other jars growth was

very slow. The seeds from jars 4-9 were planted in moist sawdust. Those from jars 7-9 had not germinated at all.

After four days, they were taken out and examined. Of group No. 9 no peas had sprouted but were covered with mould. 7 out of 11 corn grains were growing with radicles .5-1 cm. long. From No. 8, 3 peas had sprouted and then moulded as had all the others. The corn had grown had grown much more than that from No. 9; one grain had a primary root 4 cm. long and 5 secondary roots, 3 of which were 1.5 cm. long; another had a primary root 3 cm. long and 1 secondary root 2 cm. long. 7 other grains were growing with roots 1-2 cm. long. In No. 7, 9 peas out of 12 had moulded without sprouting, 2 sprouted and then died, and the other one was growing with a radicle 1.2 cm. long. All the corn was growing but one grain. The primary roots were from 2 to 6.6 cm. long. In No. 6, 6 peas out of 10, had sprouted and then died. Another had a short, curled radicle, and the 3 others were growing, with radicles 4.5-5 cm. long. Of the corn, 3 seedlings seemed much stunted, but the other 7 were very vigorous with roots 4-7.5 cm. long and stems 1.4-1.9 cm. long. In Nos. 4 and 5 about half the seeds had germinated while in the jars. The seedlings of

No. 5 were not so large as No. 6 and those of No. 4 were still smaller. In No. 5, 6 peas had roots 4-5 cm. long, and 5 had only very short sprouts. 4 corn seedlings had roots 5.2-5.4 cm. long and stems .8-1.5 cm. long. 3 seedlings were much stunted. In No. 4, 2 peas had died, 3 were very much stunted and 4 had roots 5-6 cm. long. Of the corn, 2 seedlings were quite small, 5 had roots 3-4 cm. long and stems .5 cm. long, and 3 had roots 6-7 cm. long and stems 1.2-1.4 cm. long.

Experiment 1 was repeated, using the same series with the omission of jars 8 and 9. The first observation was made 17 hours after setting up the experiment. The seeds germinated in each jar were as follows: in No. 1, 3 corn grains; in No. 2, 2 peas and 3 corn grains; in No. 3, 2 peas and 1 corn grain; in No. 4, 2 peas and 1 corn grain; in Nos. 5-7, none.

Again after 26 hours the seeds were examined. In No. 1, 4 corn grains had radicles 1.8-2 cm. long, 4 were just barely sprouted and 2 showed no growth. 5 peas had radicles 1-2 cm. long, and 3 had the radicles just barely through the seed-coats. The other 2 had not germinated. In No. 2, 8 corn seedlings were growing but were behind those in the control. The peas show the same

retardation. In No. 3, every corn grain had germinated and 1 had a radicle 2.5 cm. long. The corn and peas were both ahead of those in Nos. 1 and 2. The seeds in the other jars showed a gradual retardation, as the amount of ether was greater. In No. 7, 3 corn grains and no peas had just barely sprouted.

At the time of the next observation 20 hours later, the seedlings in No. 2 were a little behind those of the control jar, but those of No 3 were very slightly ahead of Nos. 1 and 2. In jars 4-7, a retardation appeared, still more marked than the day before. No more seeds had germinated in No. 7 and growth had about ceased.

The next day, the seedlings of No. 3 were still a little than those of Nos. 1 and 2 but in another 24 hours the control seedlings were ahead of all the rest. They did not grow as well as they should have done, however.

Conclusions: Germination and growth are very slightly accelerated by the vapour from ½ cc. of ether in 200 cc. of water. Stronger vapours retard germination proportionally more as the strength of the vapour is increased. Peas are more easily injured by ether vapour than corn. Peas in the vapour from 3 cc. or 4 cc. of ether in 200 cc. of water are prevented from germinating and

their vitality is destroyed after exposure for two and one half days. Corn subjected to the same treatment will not germinate while in the vapour but does so when removed and planted. The seeds which germinated in the ether vapour and then were transferred to sawdust seemed to be affected more than those which did not germinate in the vapour, for when it came directly in contact with the radicle tip, the injury was greater.

Ammonium hydroxide Vapour.

Experiment 1. Eight jars were prepared for germination chambers, form (b.), and to the 200 cc. of water in each jar was added ammonium hydroxide in the following quantities:

No. 1.	0. (control)	No. 5.	3 drops.
" 2.	½ drop.	" 6.	4 "
" 3.	1 drop.	" 7.	5 "
" 4.	2 drops.	" 8.	6 "

Ten corn grains and ten peas were placed in the basket in each jar. The corn had been soaked 24 hours and the peas, 12 hours.

The first observation was not made until 25 hours after the experiment was set up; then the seeds in Nos. 1-4 were about parallel as to the amount of growth, with perhaps a very slight acceleration noticeable in Nos. 2 and 3. Observation was not made soon enough to be sure whether or not, germination had been hastened. In the other jars, development was retarded the more, the more hydroxide there was present. In Nos. 7 and 8 no seeds had yet germinated.

After the next 19 hours, the seedlings in Nos. 2 and 3 showed quite an evident acceleration compared with the control; those in Nos. 4 and 5 were only slightly retarded, but the others were very much so. In No. 8 only two peas had germinated.

At the end of another 24 hours, the radicles of the seeds in the different jars measured as follows:

No.	Peas.	Corn.
1.	2 – 2.4 cm.	.8 – 1.2 cm.
2.	2.2 – 3 "	1 – 1.3 "
3.	2.1 – 2.7 "	1.2 – 1.5 "
4.	1.5 – 2.1 "	.5 – .8 "
5.	1.2 – 2 "	.3 – .7 "
6.	1.1 – 1.8 "	.2 – .7 "
7.	1 – 1.3 "	.2 – .6 "
8.*	9 and 1	

* Only two peas had germinated, and in only two corn grains had the embryo broken through the seed-coats.

These data show that the growth of the seedlings had been accelerated by the vapours from the amounts of ammonium hydroxide in jars 2 and 3, and retarded in the rest of the series an amount proportional to the concentration of the vapour.

The next observation was made after 24 hours. The lengths of the roots of the seedlings in the different jars were measured and found to be as follows:

No.	Peas.	Corn.
1.	2.5 – 3.4 cm.	1.5 – 1.8 cm.
2.	2.9 – 3.4 "	1.6 – 1.9 "
3.	2.9 – 3.5 "	2 – 2.1 "
4.	2.4 – 3.2 "	1.2 – 1.5 "

5.✓	2 - 2.3 cm.	.5 - .7 cm
6.✓	1.3 - 2 "	.8 - 1. "
7.✓	1.2 - 1.8 "	.6 - .9 "
8.*		

✓Sprouts curled abnormally.
*No development since last observed.

From these measurements we found that the control plants had been growing well and that those in No. 2 were about the same size, perhaps a very little ahead, though not so much as the day before. In No. 3 the acceleration of growth was quite apparent, but in Nos. 4-8, gradually increasing retardation just the day before, and even more marked. By this time in groups 5-8, growth had entirely ceased, and in a day or two the seeds began to mould.

The fifth observation was made 25 hours later. The control seedlings were not growing very well; the roots of the peas were 2-4.3 cm. long and somewhat curled, and of the corn, 1.9-2.3 cm. long. In group No. 2 the pea-roots were 3.3-3.7 cm. long and the corn-roots, 1.4-2 cm. long, i.e. on the average, very slightly ahead of the control. The plants in Nos. 3 and 4 were undoubtedly ahead of the control plants, those of No. 3 having been accelerated a little the more. The roots of some of these plants reached down into the solution and seemed to be benefitted by it.

The next day the plants in Nos. 2 and 4 were about the same size and just a little ahead of the control. Those in No. 3 had grown quite rapidly and were much larger than any of the others. Within another day the plants in Nos. 1, 2, and 4 had almost quit growing but those in No. 3 still grew rapidly. Three days later, one corn plant in No. 3 had a stem 14 cm. long and the other seeds were growing well. In three more days, the large corn plant in No. 3 stood 23 cm. high above the old seed, and had a vigorous root system. The other plants in the jar were still growing but not nearly so rapidly.

Experiment 2. The strengths of solutions used this time were the same as in the first half of the series used in Experiment 1.

No. 1. 0 (control) No. 3. 1 drop.
" 2. ½ drop. " 4. 2 drops.

16 hours after starting the experiment, the seeds were examined. In No 1, no seeds had germinated; in No 2, 1 pea and 2 corn grains had the radicles just through the seed-coats; in No. 3 the radicles of 2 corn grains had appeared, and in No. 4. no seeds had germinated. So the vapours in Nos. 2 and 3 hastened germination.

At the end of the next 24 hours, 9 corn grains of the control seeds had germinated,

but the radicles were only .3-.5 cm. long. 5 peas were growing with radicles .3-1.5 cm. long. In No. 2, 8 corn grains were growing, and were quite a little ahead of the control corn seedlings, their radicles being .8-2. cm. long. The peas were not growing so well; only three had germinated but one had a radicle 2.5 cm. long. Of the group No. 3, every corn grain had germinated and was growing a little better than the corn of No. 2. The peas were behind the control peas; only two had germinated. In No. 4 all the corn grains were growing. They were a little ahead of the control but not so much so as those in Nos. 2 and 3. Six peas had germinated and were growing better than those in Nos. 2 and 3.

At the time of the next observation, 21 hours later, the control plants were not growing very well. The pea-radicles were 1.2-1.8 cm. long but 3 or 4 peas had begun to mould. Only 5 or 6 corn grains were growing well, with radicles 1.9-2.9 cm. long. The seedlings in No. 2 were considerably ahead of the control seedlings. The peas had radicles 1.9-3.2 cm. long, and the corn, 1.8-4. cm. long. The peas in No. 3 were behind those in Nos. 1 and 2, for only 4 were growing and the radicles were 1 cm. long and less. The corn of this group had been accelerated still more than in No. 2, the radicles being 2.5-4.2 cm. long. In No. 4, 8 peas

were growing slightly better than in No. 3, but the corn was behind that in No. 3.

The last observation was made after 31 hours more. Nos. 1 and 4 showed about the same amount of growth, but the control plants had not grown as well as they should have done under natural conditions. The growth of the plants in Nos. 2 and 3 had been somewhat accelerated.

Conclusions: The vapour from solutions of ammonium hydroxide made by adding ½ drop and 1 drop respectively to 200 cc of water hastens the germination of corn grains and accelerates the subsequent growth of the seedlings. This effect is more marked in the case of the weaker solution. With respect to peas, their growth is retarded a little by this stronger vapour, but the vapour from ½ drop to 200 cc. of water, hastens their germination and later accelerates growth.

Camphor Vapour.

Experiment 1. Five germination chambers, form(b), were prepared and a saturated aqueous solution of camphor was made. Then to each jar was added 200cc. of solution which was, in the respective jars, as follows:

No. 1. Water (control)
" 2. 1/8 saturated solution.
" 3. 1/4 " "
" 4. 1/2 " "
" 5. saturated "

Within 15 hours after putting the seeds into the jars, in No. 1, 3 corn grains and 1 pea had just barely germinated; in No. 2, 3 corn grains and 3 peas; in No. 3, 2 corn grains and 3 peas; in No. 4, 1 corn grain and no peas; and in No. 5 the embryo of one corn grain had just split the seed-coats. Germination was hastened a little in Nos 2 and 3.

At the end of the next 24 hours, most of the seeds in the control were growing well. The growth in No. 3 had been about the same as in the control and in No. 2 it had been a very little greater. The seedlings in Nos. 4 and 5 showed a marked retardation of growth proportional to the amount of camphor vapour present.

Within another 24 hours, the seedlings

in No. 3 had fallen behind the control in rate of growth, but those in No. 2 were still farther along than the control plants. The latter had not grown normally well, however. A very decided retardation was shown in Nos. 4 and 5.

Four days after this, growth had almost ceased in all the jars. The seedlings in No. 2 whose roots reached to the water were growing better than the control plants. In Nos. 3, 4 and 5, the growth of the seedlings was retarded proportionally as the vapour was more concentrated. In No. 5, 5 corn grains had germinated, but the radicles dried up when about .3 cm. long, and the two peas which germinated stopped growing when the radicles were only .6 and .7 cm. long. A greater percent of the seeds germinated in No. 4, but they could not grow in the poisonous vapour. The roots were checked and the stems in some instances grew to be the longer, which is an abnormal condition in seedlings so young.

The experiment was repeated, the conditions being as nearly as possible, the same as before.

After the seeds had been exposed to the vapour for 17 hours, an observation was made. The number of seeds germinated in each jar was as follows: in No. 1, none; in No 2, 3 corn

grains and 1 pea; in No. 3, 1 corn grain; in No. 4 none; and in No. 5, none. This is identically the result obtained the first time, a hastening of germination in Nos. 2 and 3.

26 hours later, in the control, 9 corn grains had germinated and the radicles were .3-.5 cm. long; 5 peas had germinated, and the radicles were still quite short. The seedlings in No. 2 were just about parallel to those of the control in development; 8 corn grains and 5 peas had germinated and the radicles were about the same length as those in No. 1, so the advantage gained by the hastened germination had already been overcome by the injurious affect of the vapour. In No. 3, 7 corn grains and 4 peas had germinated; in No. 4, 5 corn grains and no peas, and in No. 5, the radicles were just breaking the seed-coats in the case of 4 corn grains. No peas had germinated. In these last two groups, growth had ceased.

The seeds were observed again after 21 hours. The control plants were growing fairly well and all the rest of the series, showed very distinctly, a gradually increasing retardation of growth, the stronger the camphor vapour was. In some corn grains, where the roots were killed when only .3 or .4 cm. long, the shoot grew to be 1 or 1.5 cm. long. In No. 5, the

radicles of the few seeds that germinated, never grew after getting through the seed-coats.

Conclusions: Camphor vapour from 1/8 and 1/4 saturated solutions slightly hastens the germination of corn and peas but very decidedly retards the subsequent growth of the seedlings. The first trial of the experiment seemed to show that the seedlings exposed to the vapour from the 1/2 saturated solution were somewhat accelerated in growth, but this was probably due to the fact that the control seedlings did not grow as well as they should have done.

Carbon bisulphide Vapour.

Experiment 1. The germination chambers used were such as those used with formaldehyde vapour, and the seeds were corn and peas as in that case. A saturated solution of carbon bisulphide was made and used in the series as follows, each jar containing 200 cc. of solution.

No. 1. Water. (control).
" 2. 1/8 saturated solution.
" 3. 1/4 " "
" 4. 1/2 " "
" 5. saturated "

When an observation was made 13 hours after the experiment was set up, the basket of seeds in No. 5 had fallen into the solution. Of the first four groups the control was undoubtedly in advance of the others, which showed a retardation in germination and in growth proportional to the intensity of the vapour present. In No. 4 the radicles were much the shortest and somewhat shrunken. The next day another basket of seeds had fallen, so the experiment was taken down and another was started, using the same series as before.

Experiment 2. The seeds had been soaked fifteen hours before being placed in

the jars. 45 hours after starting the experiment, the following observations were made: in the control jar, the peas had radicles about 1.5 cm. long, and the corn was just beginning to germinate. The seeds of No. 2 were much retarded; no pea had a radicle longer than .5 cm., and the corn had not sprouted. In No. 3, only 2 peas had the radicles just appearing, and no corn had germinated. Of groups Nos. 4 and 5, no seeds had germinated.

In another 24 hours, the peas in the control had radicles 2.5-3 cm. long. The corn was growing, but was a little slower than the peas. In group No. 2, no pea-radicle was longer than 1 cm. The seeds in Nos. 3, 4, and 5 had developed none since last observed. By this time, growth had been entirely suspended in all the jars containing the poisonous vapour. After 48 hours more, the seeds were all planted in moist saw dust. They had been exposed to the vapour for about five days. None of the seeds from Nos. 4 and 5 ever germinated, so ~~that~~ the vapour must have killed the embryos. All the peas from No. 3 had germinated after 24 hours in the sawdust and the seedlings from Nos. 1 and 2 had grown some. After 48 hours in the sawdust, the seedlings from Nos. 2 and 3 showed a very decided retardation of growth proportional to the strength of the vapour to which the

seed had been exposed.

The seedlings were next examined three days later. Of the peas in No. 3, all but 3 had died soon after germination, and these had grown very little, for the plants were quite small and unhealthy looking. The corn grains of this group all grew but the seedlings were quite different in size. Three plants were much stunted, the stems being 1.4 - 3 cm. long and the roots 1.6 - 2.8 cm. long. Here the marked retarding of the growth of the roots and the proportionately greater growth of the stem were quite evident. Two other corn plants were quite normal as to the development of parts, for the stems were 6 - 8 cm. long and the roots 13 - 14 cm. long, but their growth had been much retarded by the action of the carbon bisulphide vapour. The plants from Nos. 1 and 2 were all growing but those in No. 2 were somewhat retarded.

Conclusions: The vapours from all the solutions of carbon bisulphide used, even the very dilute ones caused a very marked retardation in both germination and growth, and those from saturated and half saturated solutions, not only prevented the seeds from germinating while exposed to it, but killed the embryos as well, after a five days' exposure.

Illuminating Gas.

Experiment 1. For germination chambers quart milk-bottles were used. [see description of germination chamber (c)]. Each bottle was graduated so that the desired amount of gas could be run in. Each contained 800cc. of atmosphere of which any desired percentage was illuminating gas and the remainder, air. For example, suppose a germination chamber was to be prepared containing an atmosphere of which 25% was illuminating gas. The bottle was graduated at 200cc. and at 800cc. Then by displacement of water, 200cc. of the gas and 600cc. of air were run in. While the bottle was still inverted over the basin of water, the bag of seeds was pushed in and the lid snapped into place. 120-150cc. of water remained in the bottle. It was then righted and immediately sealed with paraffine.

Four sets of germination chambers were prepared in this way. In each set the series was as follows:

No. 1. Pure air (control)	No. 4. 1/4 gas
" 2. 1/16 gas	" 5. 1/2 "
" 3. 1/8 "	" 6. Pure "

Set No. 1 was subjected to a temperature of 12°C.-13°C.; No. 2, 17°C-20°C.; No. 3, 21°C.; and No. 4, 36°C.-38°C.

Set No. 1. 12°C-13°C. 15 hours after the exper-

iment was set up, no seeds had germinated. 55 hours later, 2 peas in the control and one pea in No. 2 had just barely germinated. An observation was again made after 41 hours. The corn was very much retarded by the cold for none of it had germinated except 2 grains in the control. The peas in the control were all growing, with radicles .8-1 cm. long. The peas in No. 2 were about the same size as in the control but only 4 had germinated. In the rest of the series a gradual retardation was shown; in No. 6, no seeds had germinated.

The fourth observation was made 30 hours later. In the control jar most all the corn had very short radicles. The peas had grown well and the radicles measured 2-2.7 cm. In No. 2 only 5 peas were growing and were about two thirds as large as those of the control. 3 corn grains had just barely germinated. Groups 3 and 4 were behind Nos. 1 and 2. The peas in No. 5 were behind those in the first four jars but the corn was undoubtedly as far along as that of the control, ahead of Nos. 2-4. In No. 6 no seeds had yet germinated.

A fifth observation was made after 17 hours. In No. 1 the pea radicles were 2.4-3 cm. long and the corn radicles, .2-.3 cm. long. In No. 2, the peas were considerably retarded,

much more so than the corn, which was almost as far along as in No. 1 The seeds in No. 3 were considerably behind those of No. 2. Then in Nos. 4 and 5 the corn was slightly accelerated, so that in No. 5 it was very little behind that in the control. In No. 6, one pea had just germinated, but none of the corn had done so.

Two days later, the radicles of the control peas measured 2-4 cm., and of the corn .7-1 cm. The seeds in No. 2 were very much retarded. In No. 3, the peas were about like those of No. 2 but the corn was a little farther along than that in No. 2. In No. 4, the corn was the same as in No. 3 but the peas were retarded more. In No. 5, the corn had almost equalled in growth the control corn seedlings but the peas had been much more retarded. In No. 6 only the one pea had germinated and it had grown very little if any.

Set No. 2. 17°C-20°C. 15 hours after the seeds were put into the jars none had germinated. The second observation was made 55 hours later. All the seeds in the control were growing well. A marked retardation was shown in No. 2 and in all the other jars, proportional to the amount of gas present.

Four days later, although all the seeds exposed to the gas had been retarded in

growth, those in No. 4 had been affected least of all and were next to the control in rate of growth. The plants in No. 2 had not grown quite so well as those in No. 3. In Nos. 3 and 4, the radicles were short and thick with the root hairs more numerous and longer than on normally grown seedlings. Also some of the radicles were spirally curled. In No. 5 there had been very little growth. The radicles were very short and curled and tapered abruptly to the tips. The peas were injured more than the corn. In No. 6, only four peas germinated and they died in a short time after the radicles were exposed to the gas.

The experiment was repeated, a series having been prepared just as before. Within 24 hours the seeds were germinating and germination was hastened slightly in No 2. In Nos. 3 and 4 the germination of the peas was about as in the control but the corn was retarded. In No. 2, more than half the seeds had just sprouted, but they were much behind the rest of the series except No. 6, where no peas and only 3 corn grains had sprouted.

16 hours after this a distinct, gradual retardation of growth was quite evident, except that the seeds in No. 4 were as far along as those in No. 2. In No. 6, most all the corn grains had germinated, but had grown very little. None of the peas had germinated.

Set No. 3. 21°C. (constant temperature box). The seeds were examined 24 hours after being put into the jars. In No. 1, 9 corn grains and 3 peas had germinated; in No. 2, 8 corn grains and no peas; in No. 3, 7 corn grains and 1 pea; in No. 4, 4 corn grains and no peas; and in Nos. 5 and 6, no seeds whatever.

17 hours later, the seeds in the control were growing and the peas and the corn were about parallel, as they were all through the series. The seeds exposed to the gas showed an increasing retardation of growth as the percentage of gas in the atmosphere was greater. In No. 6, most all the seeds had just germinated.

When examined again in two days, the control seedlings were growing quite naturally, and those of the rest of the series showed still more plainly the retardation which was noticed before. This time, however, the peas had been affected more than the corn. In Nos. 2 and 3 some of the radicles were spirally turned and densely clothed with root hairs.

Set. No. 4. 36°C. - 38°C. 19 hours after the set was prepared, the seeds were observed. In the control, no peas had germinated but 7 corn grains had done so, one having a radicle 1 cm. long. In No. 2, 9 corn grains and 2 peas had germinated, undoubtedly showing a

slight acceleration.

2½ hours later, the control corn showed a rapid growth, being quite noticeably farther along than earlier in the day. Only 2 peas had germinated. In No 2, 2 more peas had germinated since last noticed. The acceleration here is still quite evident. In No. 3, germination was not so good as in the control. 8 corn grains were growing a little, but no peas had yet germinated. In No. 4, 3 corn grains and no peas had germinated; in No. 5, the radicles of 4 corn grains were just breaking through; in No. 6, no seeds had germinated.

In another 17 hours, the corn roots in the control were 2-3 cm. long. The peas had grown scarcely at all, but had evidently been much retarded by the heat. In No. 2 the roots seemed stunted, tapered abruptly, were densely covered with root hairs and were twisted spirally. Nos. 3-6 showed a retardation, increasing rapidly as the gas mixture was more concentrated. No peas had germinated in jars 4-6. In No. 6 only one corn grain had the tip of the radicle just through the seed-coats

The fourth observation was made 30 hours later. The corn plants in the control were growing rapidly. The peas were very much slower. In No. 2 there had been very little growth since the day before and in Nos. 3-6,

growth had practically ceased.

16 hours after this, the roots of the corn in the control measured 3-4 cm. long. In jars 2-6 there had been very little if any change since they were examined last.

Conclusions: In the lower temperatures, corn is retarded by the cold, and the illuminating gas does not injure it so much as it does in higher temperatures. On all the seeds, the effect of the gas is intensified by an increase in temperature. In the cold room, the peas grow better than the corn does, so they are injured more than it is, growth being more retarded. In an atmosphere, 1/16 illuminating gas, at temperatures 20°C.-38°C. germination is very slightly hastened; growth is in all cases retarded by the least quantities of the gas. In atmospheres, 1/16-1/8 illuminating gas the roots are turned and twisted spirally. Molisch observed that this is a characteristic habit of roots in an atmosphere lacking the proper amount of oxygen.

Hydrogen and Carbon dioxide.

Experiments were set up for the purpose of determining the effect of different percents of both hydrogen and carbon dioxide upon the germination of seeds and the growth of seedlings. Germination chamber (c) was used, but the method of sealing was not satisfactory, for when the first observation was made, the jars in which the highest percents of gas were placed had been unsealed by the expansion of the gas due to a rise in temperature. However, it was observed that in the jars which came unsealed, the seeds had germinated much better than in those which still contained the gas, as put in. So these gases must have a retarding effect upon germination.

The Effect of Gases and Vapours in Solution upon Transpiration.

Experiment 1. A number of twigs of Syringa (lilac) were picked, placed in water, the stems cut off under water, and left over night. The next day, four series of 100 cc. bottles were prepared; the first series contained different percent solutions of ether; the second, of carbon dioxide; the third, of illuminating gas, and the fourth, of carbon bisulphide. A saturated solution was made of each of the reagents and the solutions for the bottles were prepared by adding so many parts of the solution to so many parts of water; for example, a 1/8 saturated solution of ether is one part of saturated solution of ether to seven parts of water. When the solutions were ready in the bottles, a leafy twig was quickly transferred to each bottle and sealed in with cotton-seed oil. The bottles were then set in a light place and weighed at intervals, to determine the loss of weight by transpiration in each case. At the end of the experiment, the leaves were taken from each twig, thoroughly dried and weighed to find the comparative leaf surface of each twig, as the transpiring leaf surface was considered proportional to the dry weight of the leaves. In order to be able

to compare the losses by transpiration in the different cases, the losses in weight were calculated with reference to the transpiring surface of one gram of dry leaves.

The following tables show the series used in each case and the respective losses of weight due to transpiration. The weights are given in grams, calculated with reference to one gram of dry leaves.

Table IX.

Ether.

No.	Stem in	Loss of weight by transpiration.							
		1st hr.	2nd hr.	3rd hr.	4th–7th hrs. average	8th–9th hrs average	10th–24th hrs average	25th–32nd hr. average	33rd–48th hrs average.
1.	Sat. Sol.	.424	.363	.43	.445	.212	* .13	.225	* .087
2.	½ " "	1.32	1.32	.34	.692	.33	.228	.325	.141
3.	¼ " "	1.38	.84	1.13	.695	.257	.143	.247	.082
4.	⅛ " "	.55	.376	.41	.332	.145	.09	.117	.043
5.	1/16 " "	.62	.5	.37	.405	.018	.088	.15	.054
6.	1/32 " "	1.12	.33	.83	.315	.18	.096	.125	.044
7.	Water.	.866	.93	1.93	1.32	.705	.355	.375	.11

*During the night.

Table X.

CO_2

No.	Stem in	Loss of weight.		
		1st–5th hrs average	6th hr.	7th–22nd hrs. average.
1	Sat. Sol.	.412	.11	* .082
2	½ " "	.446	.13	.093
3	¼ " "	.22	.14	.081
4	⅛ " "	.186	.09	.045
5	Water	.28	.15	.054

*During the night.

Table XI.

Illuminating gas.

No.	Stem in	Loss of weight. 1st–3rd hrs average	4th–6th hrs average	7th–22nd hrs average
1.	Sat. Sol.	.266	.116	* .061
2.	½ " "	.34	.12	.06
3.	¼ " "	.53	.143	.07
4.	⅛ " "	.376	.133	.062
5.	1/16 " "	.476	.212	.103
6.	Water	.196	.102	.052

*During the night.

Table XII.

CS_2

No.	Stem in	Loss of weight by transpiration. 1st hr.	2nd–5th hrs average	6th–7th hrs. average	8th–22nd hrs average	23rd–31st hrs average.	32nd–47th hrs. average
1.	Sat. Sol.	.706	.35	.24	* .075	.097	* .05
2.	½ " "	.68	.387	.158	.1	.165	.06
3.	¼ " "	→	.725	.285	.166	.237	.11
4.	⅛ " "	1.105	.59	.275	.141	.255	.094
5.	1/16 " "	1.66	1.82	1.045	.482	.389	.1375
6.	Water	.446	.27	.13	.074	.076	.038

*During the night.

These tables all show that transpiration is less during the hours of the night than during the day. From Table IX, it is seen that the general effect of ether is a depression of the transpiration stream. However it did not act this way until the third hour, where the solutions used were ½ and ¼ saturated; in fact, in these cases a slight acceleration was shown at first. During the remaining 46 hours of the experiment, the transpiration of

the plants standing in ether solutions was constantly less than that of the control plant; but it is quite notable that the solutions containing the least ether retarded the transpiration more than did the saturated and the $1/2$ and the $1/4$ saturated solutions; of these latter, however, the saturated solution had the most retarding effect.

Table X shows that with the plants in the saturated and $1/2$ saturated solutions of carbon dioxide, the transpiration was very slightly increased above that of the control. In the cases of the $1/4$ and $1/8$ saturated solutions the transpiration was retarded during the first six hours only a very little and was finally accelerated here also. These solutions used contained a very small amount of carbon dioxide so the results obtained agree with the conclusions of Dr. Kosaroff, that although a large quantity of carbon dioxide exerts a strong depressing influence upon the absorption and transpiration of water in plants, small quantities accelerate transpiration, as also Sachs and Burgerstein found in their research. The plants in the strongest solutions wilted somewhat, because the rate of absorption of water was not increased sufficiently to supply the increased loss by transpiration.

By a study of Table XI, we find that the plants standing in solutions of illum-

inating gas transpired more water than did the control plant. This acceleration was inversely proportional to the amount of gas in the solution, the saturated solution causing the least acceleration. During the experiment, the plants all wilted, the ones in the strongest solutions wilting first, so the absorption of water was not accelerated with the transpiration but probably retarded somewhat. The wilting, as Kosaroff says, may have been due to increased transpiration or to decreased absorption, or to both of the factors combined. If it had been due only to the greater amount of water transpired while the amount absorbed remained normal, the wilting would have been most marked where the acceleration of transpiration was the greatest. This was not the case, however, for the wilting of the plants in "soon-ness" and degree was directly proportional to the amount of gas in the solution, while the acceleration of transpiration, as said before, was inversely proportional; so it must have been caused by both increased transpiration and decreased absorption. When the leaves were dried in the oven, a strong odor of the gas was noticed, so it must have been drawn up into the leaves, where it undoubtedly killed some of the cells; therefore some of the water given off from the plant must have been simply evaporated from the

dead tissues as they dried.

Table XII shows that the effect of carbon bisulphide in the solution is identical with that of illuminating gas, only much more marked in degree. The transpiration was accelerated inversely proportionally compared with the amount of carbon bisulphide present, and the wilting of the leaves was directly proportional. So, like illuminating gas, carbon bisulphide in very small quantities decreases the absorption of water and increases the transpiration. As carbon bisulphide is very poisonous to plants, the carbon bisulphide drawn up into the leaves must have injured the tissues, so that here, too, some of the water given off was evaporated from dead or dying tissues.

Conclusions.

There is no definite relation between the amount of oxygen present in the water and the percentage of water absorbed by soaking seeds. This imbibition of water is a purely physical process. Seeds soaked in water containing a maximum amount of oxygen are accelerated in germination, and those soaked in water deprived of oxygen are retarded.

Of seeds germinated in water, those in the water containing a maximum amount of oxygen, germinated sooner and grew longer than those in ordinary water. Seeds in boiled water germinate about as soon as normally but die sooner than seeds in aërated water.

The lack of oxygen in the water or solution in which a plant is growing retards its growth, absorption, and transpiration.

The stimulating effect of decreased oxygen-pressure accelerates for a time the growth of the primary roots of Vicia faba. Decreased oxygen-pressure in the presence of nutrient salts acts as a stimulus slightly accelerating transpiration.

The vapour from ½ cc. of 40% formaldehyde in 200 cc. of water hastens germination somewhat. Vapours from stronger solutions retard germination and finally prevent it

entirely, but the vitality of the seeds is not destroyed. Formaldehyde vapour always retards growth and finally kills the seedling.

Carbon bisulphide vapour is very poisonous to plants. It retards germination and growth. The stronger vapours not only suspend the activities of germination but destroy the vitality the vitality of the seeds.

The vapour from an exceedingly weak solution of ammonium hydroxide hastens germinates and accelerates the subsequent growth of the seedlings. Stronger solutions retard both germination and growth.

Camphor vapour retards growth proportionally to the strength of the vapour. A very weak vapour of camphor hastens germination.

Germination and growth are very slightly accelerated by the vapour from ½ cc. of ether in 200 cc. of water. Stronger solutions have a decided retarding effect. Ether depresses the transpiration stream.

Illuminating gas is poisonous to plants and acts more injuriously as the temperature rises. It retards growth in all cases, finally killing the plant. At a temperature 20°C. - 38°C. an atmosphere 1/16 illuminating gas slightly hastens germination.

Very small amounts of carbon dioxide

accelerate transpiration.

Carbon bisulphide and illuminating gas in solution accelerate transpiration inversely proportionally to the percent of the saturation of the solution.